POSSIBLE ACTION OF THE SEX-DETERMINING MECHANISM

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Sex is the dual expression in organisms of a common series of characters which are unequally and reciprocally developed in the individuals of the two classes, the essential and primary difference between which is the presence of germ cells of two types—ova in the female, sperm in the male. Sex is not a necessity for reproduction or for biparental inheritance: it *is* required in reproduction of highly complex organisms. It exhibits many modifications of appearance and intensity in different groups and ranges from apparent correspondence of the two classes to wide extremes of dimorphism. While this gradation prevails for organisms in general, the individual is usually fixed in its status of differentiation. In exceptional cases the individual may possess the primary characters of both sexes or may alternately exhibit one or the other. The measure of difference in any case is cellular. The first observable cellular difference consists in a differentiation of conjugating cells into larger passive food-laden ova, and smaller, active sperms. Similarly the individual, ripe germ cell of either class appears definitely fixed in its character. The primary measure of difference between the two types of germ cells is now demonstrated to be nuclear, and, specifically, chromosomal. Sex is thus shown to be a cellular problem.

Any conception of the sex determining mechanism must conform to the different conditions of range and intensity of sexuality manifested by organisms. As the conditions in one type of sexuality can not be substituted for another, so the character of the determinant in one case can not be implied directly in another. The details of the mechanism are variable in correspondence with the conditions it determines.

In one type, in which the relation was first determined, the alternative character is definitely fixed and the body cells are individually and independently male or female in type. The mechanism of determination here shows itself to be characterized by a difference of one chromosome more in the female than in the male. This is a particular chromosome, marked by such peculiarities in the male as to make it readily determinable. Since this element is the measure of the differences between the male and female types of cell, and therefore the measure of the difference between the male and female animal, a study of its differential behavior should be of value in arriving at conclusions regarding the nature of sex and the method of its determination.

The two principal observations upon which an explanation of the operation of the sex determining mechanism must rest are (1) the duplex and alternative chromosome series, paralleling the double control and alternative inheritance of characters, and (2) the physical state of the active chromosomes. Sex,

being a case of strict alternative heredity, would necessarily require a method of control which should unfailingly operate to produce one or the other condition, and, since the numbers of males and females are approximately equal, it should also conform to this numerical requirement. The presence and behavior of the accessory chromosome supplies the theoretical demands of such a control. It is exactly alternative in its apportionment to the male cells, producing two equal and differentiated classes; and, aside from their unequal speed of approach to the egg, and selective attraction by it, should go into exactly half the ova. This behavior has been determined accurately and is no longer questioned.

The alternative mechanism is evident in the behavior of the accessory chromosome. It has not been clear why there should be a double condition of the sex chromosome in the female—in this respect conforming to the ordinary conditions—and a single representation in the male. The condition obtains however and in this fortunate circumstance we find the most promising approach to an understanding of the essential character of sex and the method of its determination. Of great significance here is the fact that, in the mechanism of the germ cells, there exists nothing of functional value in one sex that is not contained in the other. For the differential element of the problem we have therefore to look, not for something that is in itself male or female, but for some factor which, in operation under one set of conditions, will so control a series of characters as to give it the aspect which represents maleness; under another set of conditions the alternative state of femaleness. How then does this differentiator function?

The simplest conception of its action, perhaps, would be to ascribe to it some specific power which, exerted to a certain degree, might eventuate in the aspect of maleness, while in double that effect the series of characters would be female. In essence this is the quantitative theory. It does not however conform to any of our ideas of the alternative, or allelomorphic, action of the chromosomes. What our experience with regard to chromosome action dictates so far is this: One control for a character is sufficient for its elaboration; two controls do not exhibit the sum of their action but find themselves in opposition and usually one or the other prevails (probably for the single cell one always does); additional controls are apparently without effect.

Genetic experiments also show that in cases of sex-linked inheritance a single control in the male has the same effect as a double identical control in the female, and that, if the factors in the female are opposed to each other, such a single control as is fully effective in the male is then only half as potent.

The evidence accordingly relates to conditions of cell constitution and explanations must be in terms of cell organization and known functions. In this respect a comparison of the sex chromosomes of the male and female at the critical time when their germ cells are being prepared for union is most instructive. While in the female there is apparent no unusual activities of the sex element, as compared with the other chromosomes, in the male there are

well marked differences both in time and degree of its action. If the results of the activities of the cell are due to the ordered interaction of its parts, then any change in the rate of any one of its controlling elements, or any modification of its time of action, must essentially affect the product. The sex-chromosome during the development of the male germ cells exhibits all the signs of such a differential action. In the first stages it is much more active than the other chromosomes, as is evidenced by the large surface it exposes at the time of greatest cellular interaction. Not only is this true but it is more independent, having its substance isolated in a separate region. From this behavior it is clear why it should, in the single condition here, be quite as effective in its action as the duplex element of the female, if similar activities prevail in the body cells.

At a later stage, when it is almost certain that the new relations between controls of characters are being established, the sex chromosome is withdrawn and has its surface reduced to the least possible extent. It gives every evidence of inactivity, and, indeed, at this time has no occasion for action, since it has no homologue with which to react. In cases, unlike the Orthoptera, where there is a member to pair with it, the behavior is much the same and the genetic evidence would indicate the absence of any reaction.

Undoubtedly this is indicative of the real difference between the female and male organization, and, when fully understood, will point to the meaning of sex. It is possible that we have here the explanation of the greater variability of the male, for if a part of the control system is thus withdrawn from action at the time of reorganization it would, almost inevitably, affect the entire result. Here it may be recalled that there has been much dispute regarding the general significance of sexual reproduction, some holding that it is to ensure variation, others that it is to control or prevent it. Since both of these ends must, in some measure, be attained is it not entirely possible that the sexes represent, in part, such a division of labor? In this connection it may be pointed out that the history of the sex chromosome is such as to fit it exactly for the rôle of furthering these two purposes. It passes alternately from the male to the female line, in the one being subject to the relative instability of its unpaired condition, in the other being an orderly member of a balanced series, forced to react with its mate as do the other chromosomes. There is a possibility that in the male, the sex chromosome being unmated, or opposed by an inactive element, may be more free to react with the other chromosomes and in this way change their constitution, being in turn affected by the reaction. By the nature of its transmission it must, after this experience, pass into the female line where its relation to the complex is necessarily different. The contrast in these two conditions is obvious and the interpretation strongly suggested.

Where there is a mate to the sex chromosome in the male the genetic results would indicate that it has no function, and the very fact that it may indifferently be present or absent suggests its inactivity. This element, of all the

chromosomes, is confined to the male line and it is possible that its loss of function is due to a lack of variable reaction. It experiences in effect, a most intensive form of inbreeding and shows the characteristic results of such unvarying reactions. For it, there is no opportunity to eliminate greater or less variables, as is the case with the x-element during maturation in the female. The ultimate problem is, of course, to determine why such a difference between homologous elements should exist.

THE STUDY OF THE SEDIMENTS AS AN AID TO THE EARTH HISTORIAN

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Objectives of the Earth Historian.—We are, of course, still immensely far from our ultimate goal, which is a complete understanding of all the past states and events of the earth, or as Professor Salisbury used to put it, "the complete geographies of all past epochs." Progress toward this unreachable goal will be most favored if the advance is made rather uniformly, all along the front. It is true that such progress is often made by pushing out salients, but the further extension of such salients is usually impossible without corresponding support from the flanks.

In the past we have gone ahead much farther along certain lines in geologic history than along others. The history of life and of faunal succession has been cultivated assiduously for generations and is, on the whole, much better understood than other phases of the subject. Although not so well known in detail, the history of diastrophism is now fairly well blocked out and the mere continuation of studies already under way is likely to afford us in the near future a serviceable understanding of the sequence of major earth movements.

The most backward points in the general advance just now are in two sectors: That of the history of climate, and that of the principles of chronology and correlation.

The importance of climate arises from the fact that it is one of the most powerful factors, if not indeed the dominant factor, controlling not only the sculpture of the land but the nature of the deposits that are made both on land and in the sea.

Secondly, the principles of correlation must be understood better than they are now, before we can bring into their proper time relations the various events and conditions of which the sediments give us record. In spite of the impressions in elementary text books of geology, I think it will be generally admitted, by those who have carefully considered the question, that we do not yet know these principles with satisfactory accuracy. If we did, we should